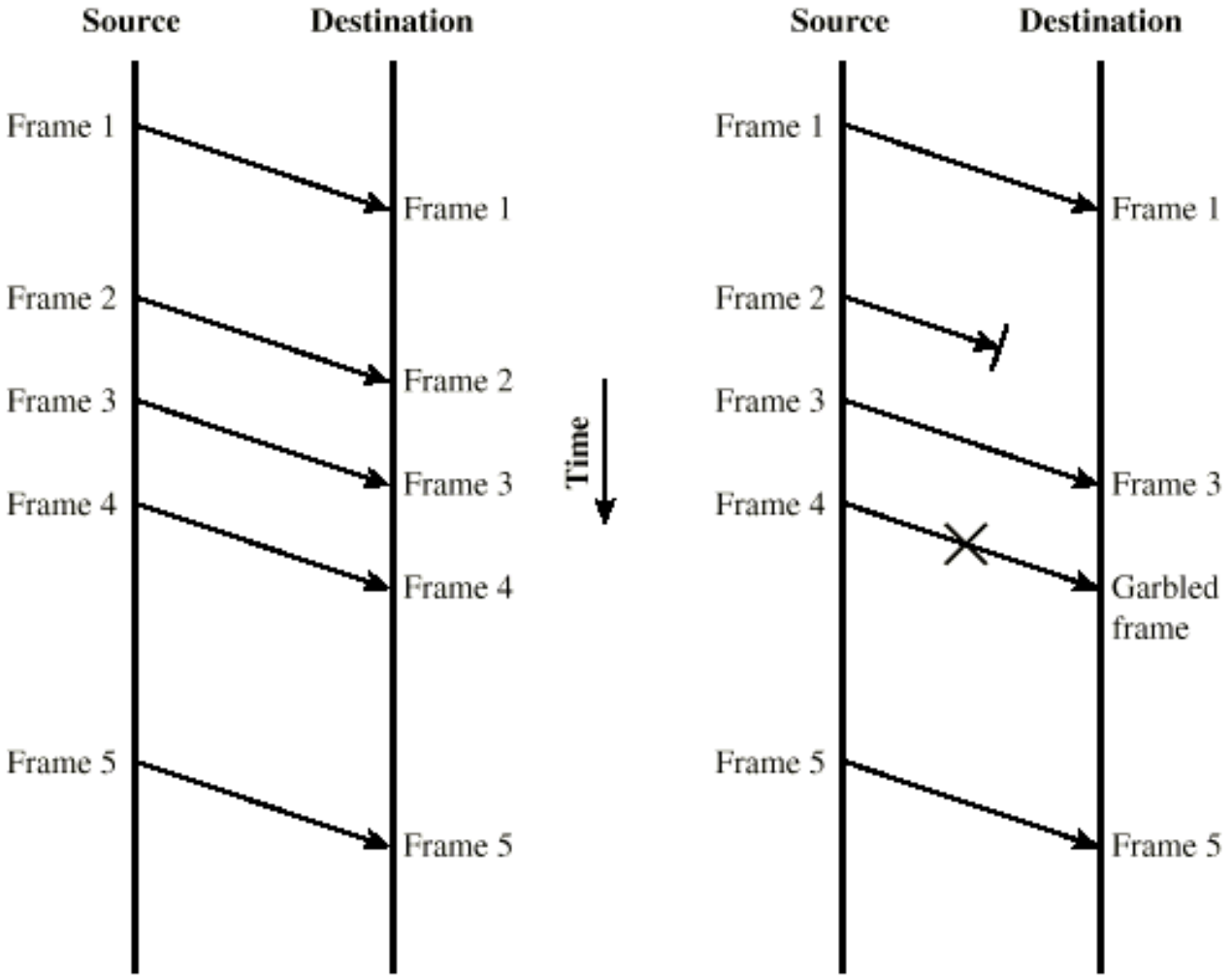
William Stallings
Data and Computer Communications
7th Edition

Chapter 7
Data Link Control Protocols

Flow Control

- Ensuring the sending entity does not overwhelm the receiving entity
  - —Preventing buffer overflow
- Transmission time
  - —Time taken to emit all bits into medium
- Propagation time
  - —Time for a bit to traverse the link

Model of Frame Transmission



(a) Error-free transmission

(b) Transmission with losses and errors

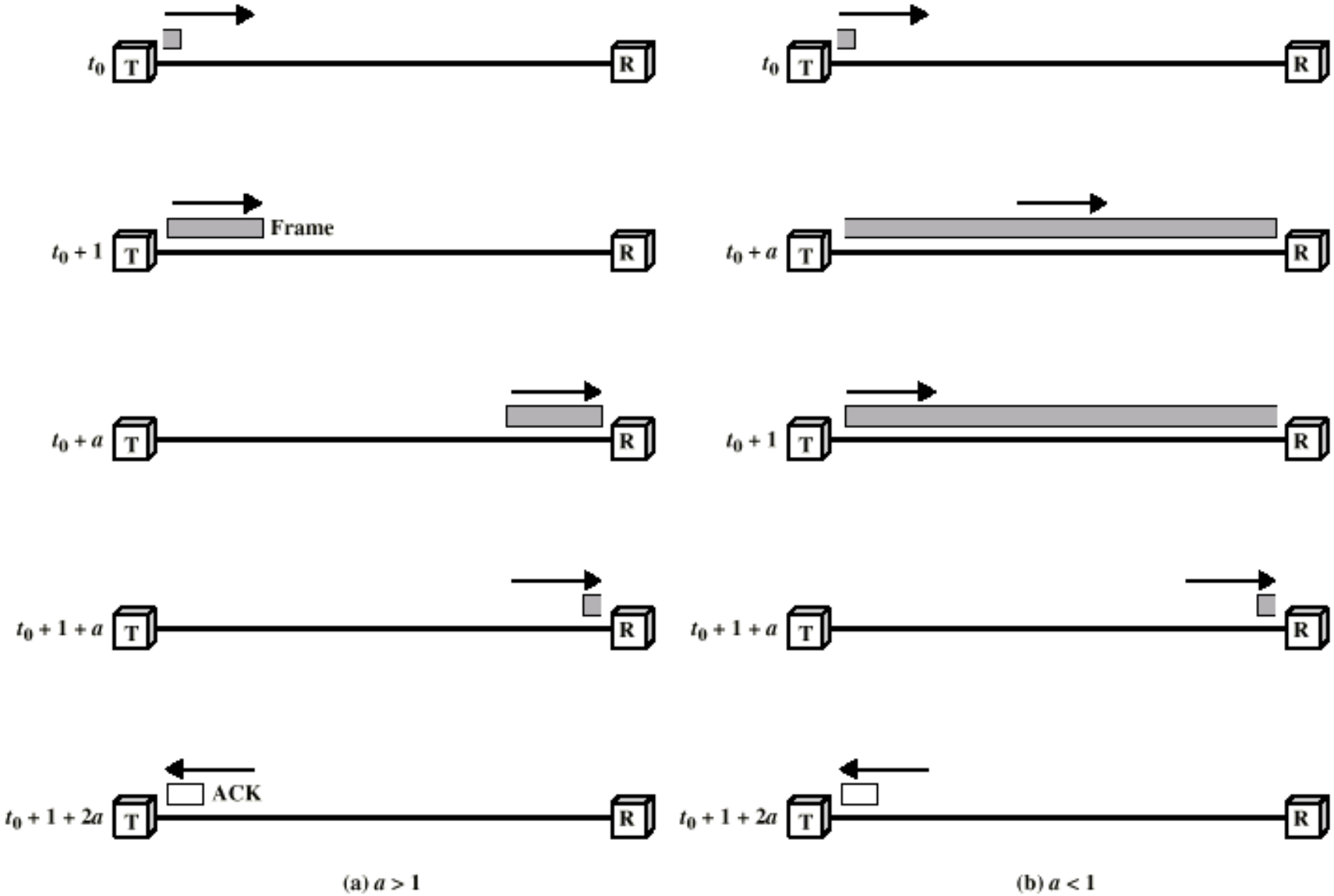
Stop and Wait

- Source transmits frame
- Destination receives frame and replies with acknowledgement
- Source waits for ACK before sending next frame
- Destination can stop flow by not send ACK
- Works well for a few large frames

Fragmentation

- Large block of data may be split into small frames
  - —Limited buffer size
  - —Errors detected sooner (when whole frame received)
  - —On error, retransmission of smaller frames is needed
  - —Prevents one station occupying medium for long periods
- Stop and wait becomes inadequate

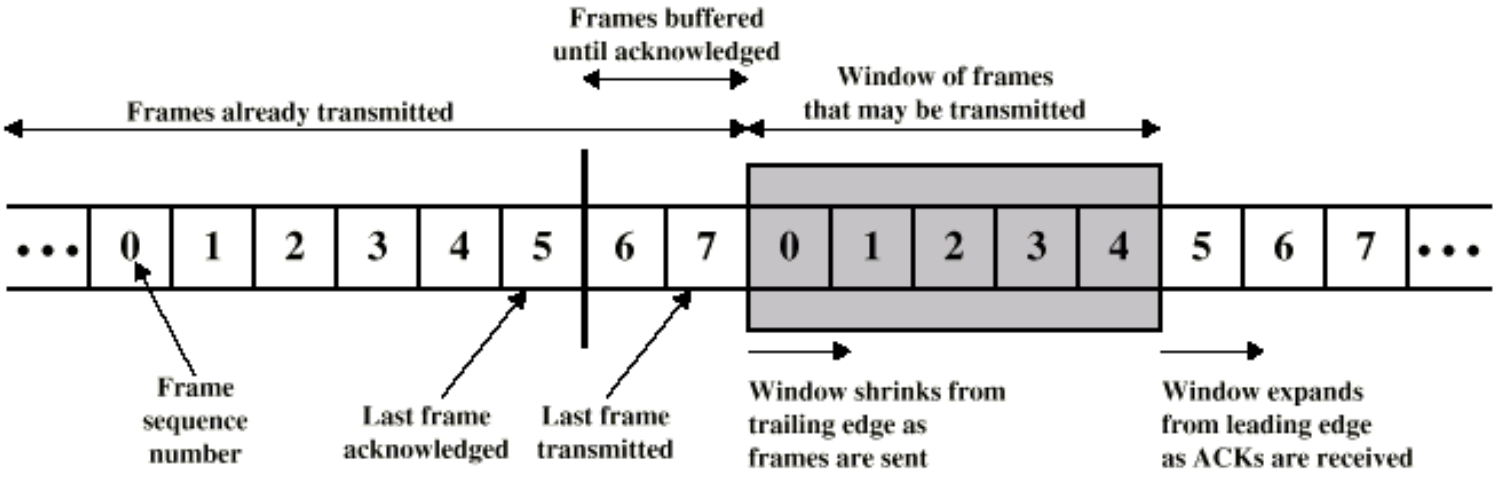
Stop and Wait Link Utilization



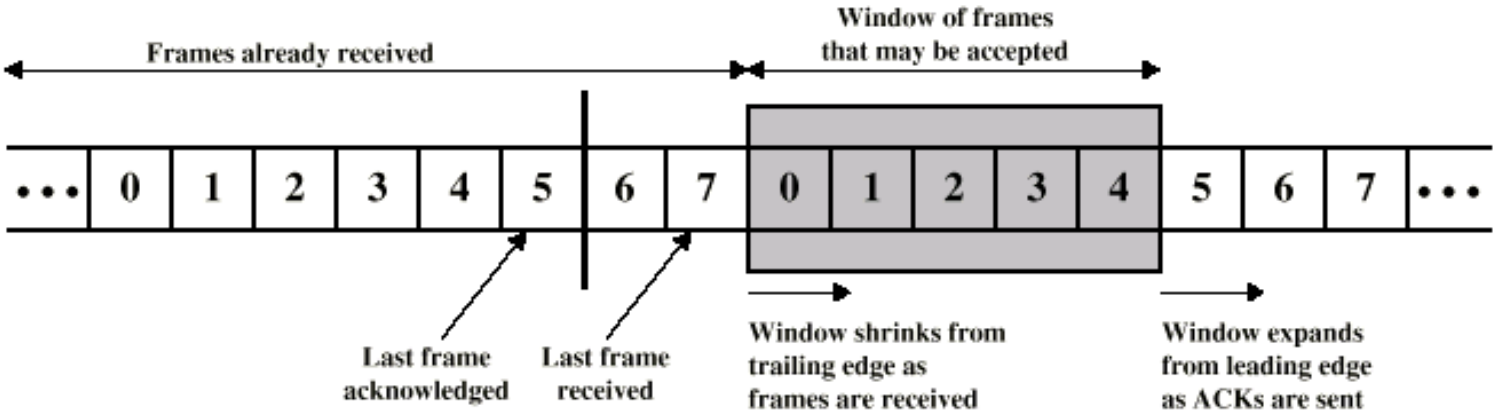
Sliding Windows Flow Control

- Allow multiple frames to be in transit
- Receiver has buffer W long
- Transmitter can send up to W frames without ACK
- Each frame is numbered
- ACK includes number of next frame expected
- Sequence number bounded by size of field (k)
  - Frames are numbered modulo 2^k

Sliding Window Diagram

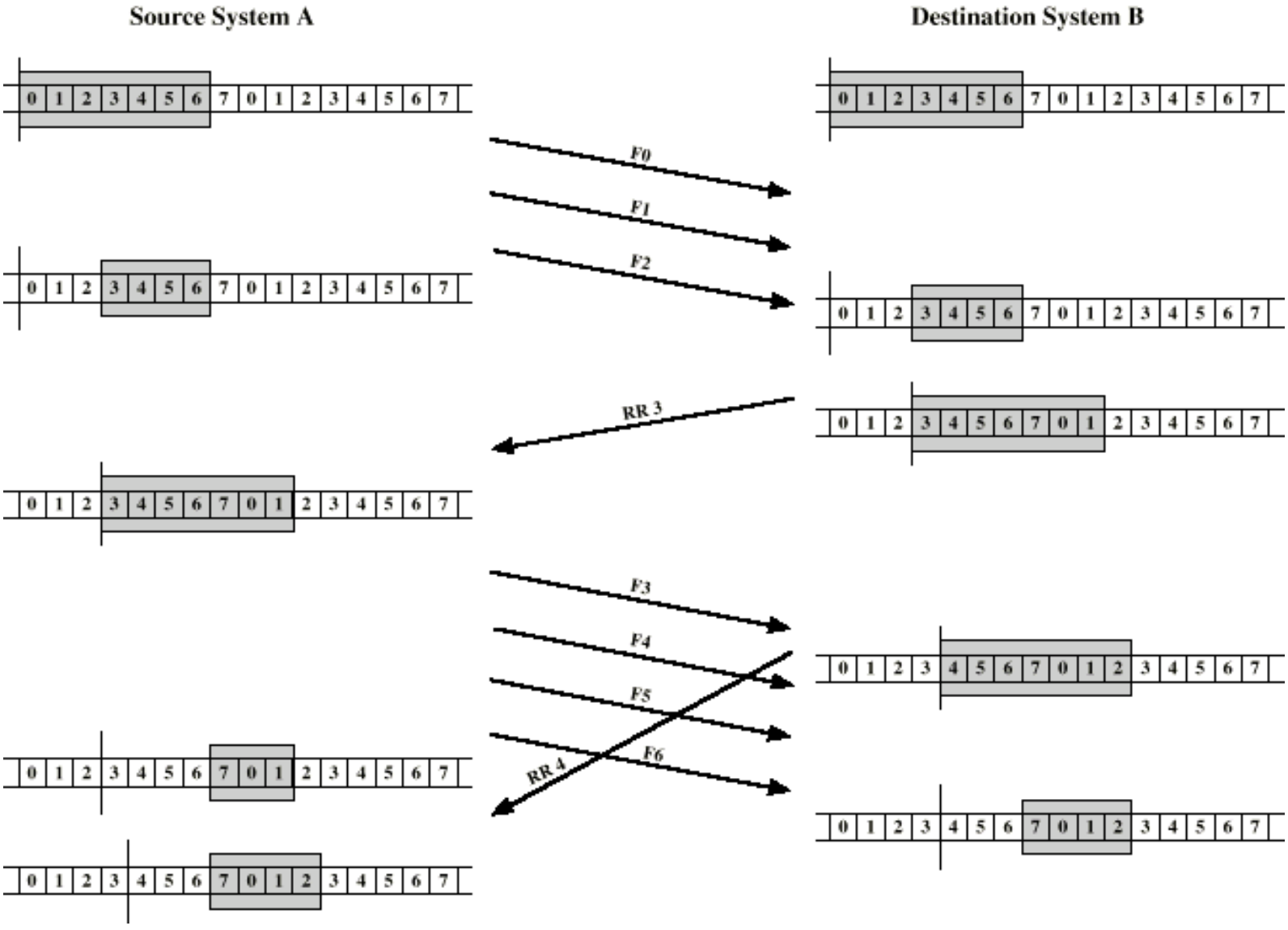


(a) Sender's perspective



(b) Receiver's perspective

Example Sliding Window



Sliding Window Enhancements

- Receiver can acknowledge frames without permitting further transmission (Receive Not Ready)
- Must send a normal acknowledge to resume
- If duplex, use piggybacking
  - —If no data to send, use acknowledgement frame
  - —If data but no acknowledgement to send, send last acknowledgement number again, or have ACK valid flag (TCP)

Error Detection

- Additional bits added by transmitter for error detection code
- Parity
  - —Value of parity bit is such that character has even (even parity) or odd (odd parity) number of ones
  - —Even number of bit errors goes undetected

Cyclic Redundancy Check

- For a block of *k* bits transmitter generates *n* bit sequence
- Transmit *k+n* bits which is exactly divisible by some number
- Receive divides frame by that number
  - —If no remainder, assume no error
  - —For math, see Stallings chapter 7

Error Control

- Detection and correction of errors
- Lost frames
- Damaged frames
- Automatic repeat request
  - —Error detection
  - —Positive acknowledgment
  - —Retransmission after timeout
  - —Negative acknowledgement and retransmission

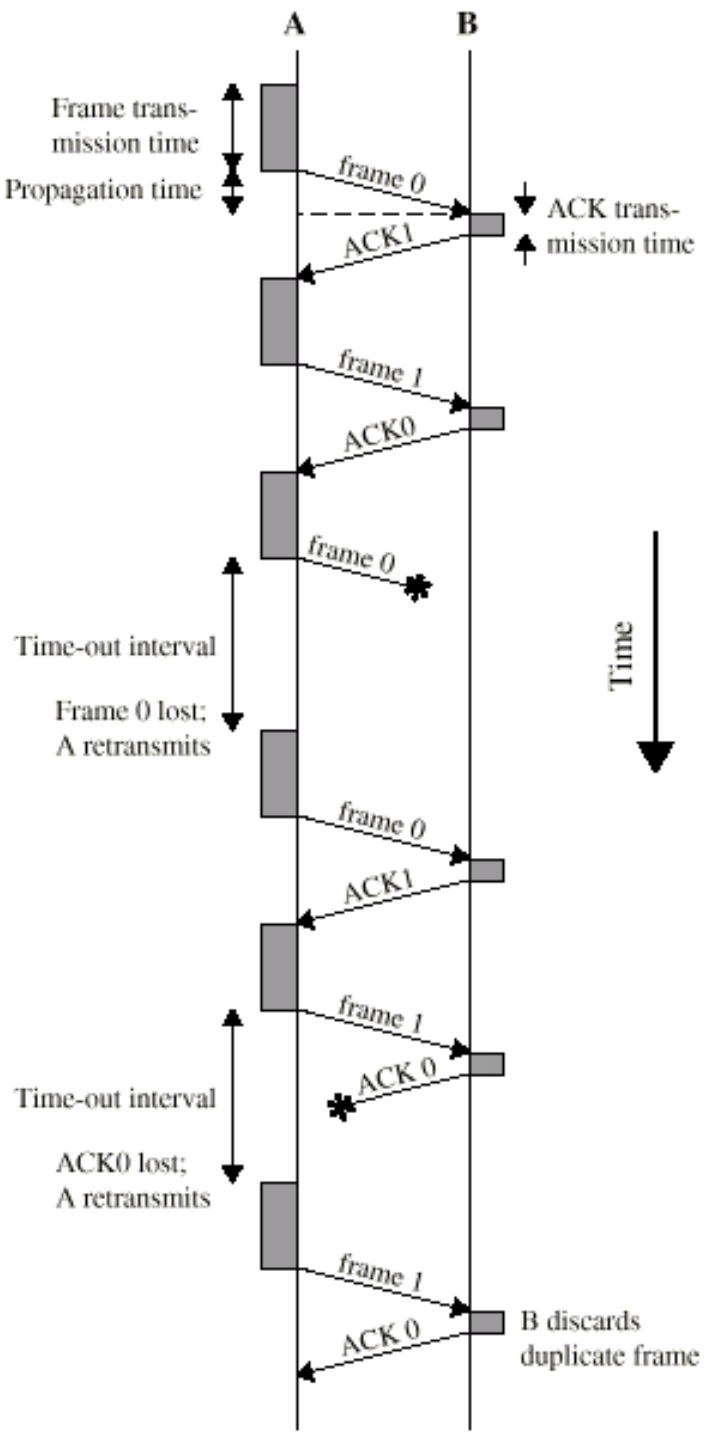
Automatic Repeat Request (ARQ)

- Stop and wait
- Go back N
- Selective reject (selective retransmission)

Stop and Wait

- Source transmits single frame
- Wait for ACK
- If received frame damaged, discard it
  - —Transmitter has timeout
  - —If no ACK within timeout, retransmit
- If ACK damaged,transmitter will not recognize it
  - —Transmitter will retransmit
  - —Receive gets two copies of frame
  - —Use ACK0 and ACK1

Stop and Wait - Diagram



Stop and Wait - Pros and Cons

- Simple
- Inefficient

Go Back N (1)

- Based on sliding window
- If no error, ACK as usual with next frame expected
- Use window to control number of outstanding frames
- If error, reply with rejection
  - —Discard that frame and all future frames until error frame received correctly
  - —Transmitter must go back and retransmit that frame and all subsequent frames

Go Back N - Damaged Frame

- Receiver detects error in frame *i*
- Receiver sends rejection-*i*
- Transmitter gets rejection-*i*
- Transmitter retransmits frame *i* and all subsequent

Go Back N - Lost Frame (1)

- Frame *i* lost
- Transmitter sends *i+1*
- Receiver gets frame *i+1* out of sequence
- Receiver send reject *i*
- Transmitter goes back to frame *i* and retransmits

Go Back N - Lost Frame (2)

- Frame *i* lost and no additional frame sent
- Receiver gets nothing and returns neither acknowledgement nor rejection
- Transmitter times out and sends acknowledgement frame with P bit set to 1
- Receiver interprets this as command which it acknowledges with the number of the next frame it expects (frame *i*)
- Transmitter then retransmits frame *i*

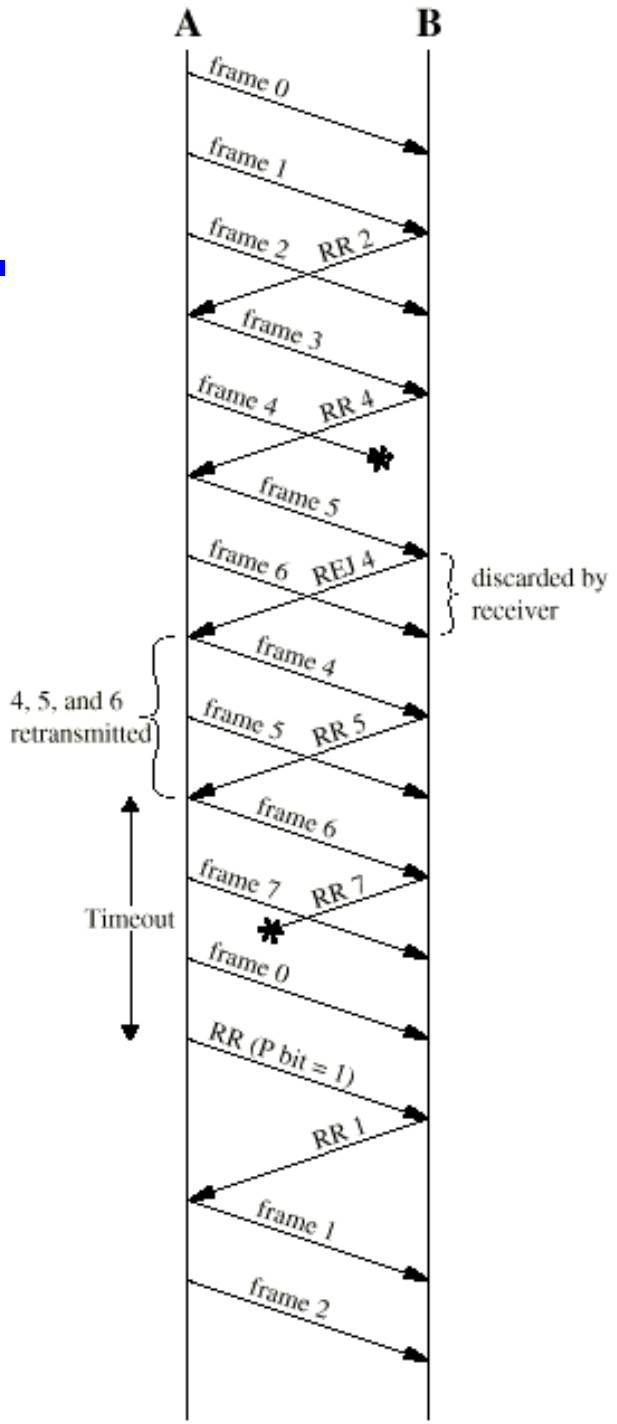
Go Back N - Damaged Acknowledgement

- Receiver gets frame *i* and send acknowledgement (*i+1*) which is lost
- Acknowledgements are cumulative, so next acknowledgement (*i+n*) may arrive before transmitter times out on frame *i*
- If transmitter times out, it sends acknowledgement with P bit set as before
- This can be repeated a number of times before a reset procedure is initiated

Go Back N - Damaged Rejection

- As for lost frame (2)

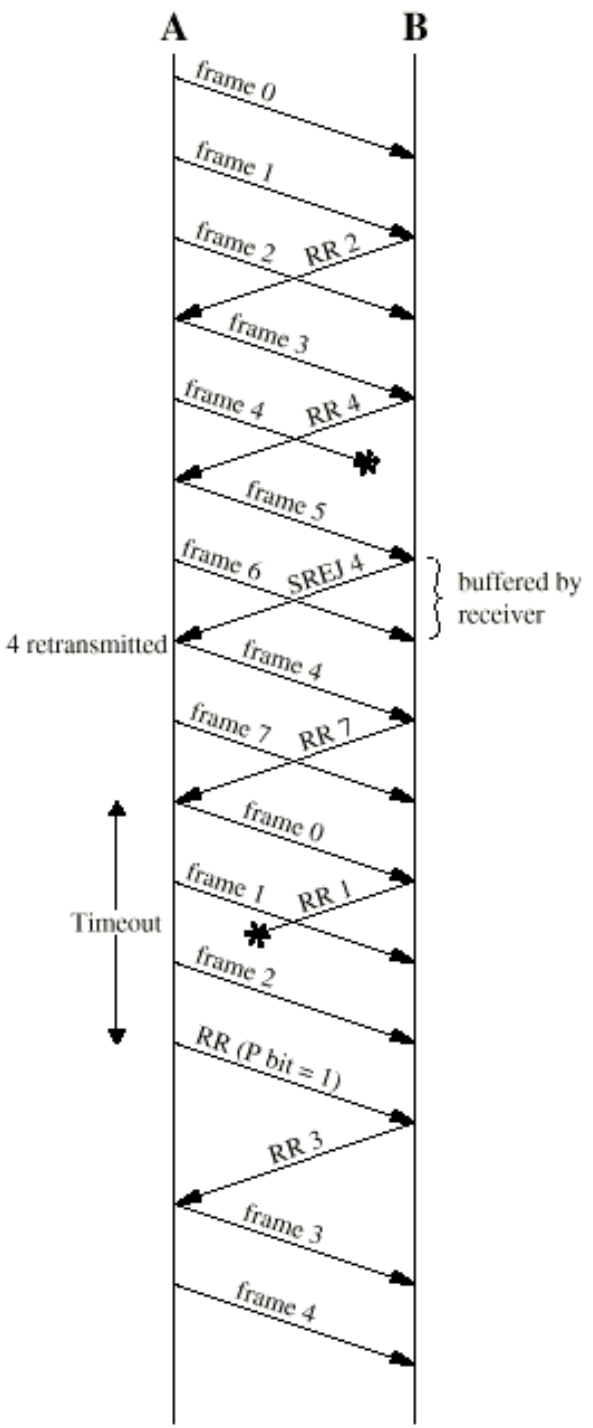
Go Back N - Diagram



Selective Reject

- Also called selective retransmission
- Only rejected frames are retransmitted
- Subsequent frames are accepted by the receiver and buffered
- Minimizes retransmission
- Receiver must maintain large enough buffer
- More complex login in transmitter

Selective Reject - Diagram



High Level Data Link Control

- HDLC
- ISO 33009, ISO 4335

HDLC Station Types

- Primary station
  - —Controls operation of link
  - —Frames issued are called commands
  - —Maintains separate logical link to each secondary station
- Secondary station
  - —Under control of primary station
  - —Frames issued called responses
- Combined station
  - —May issue commands and responses

HDLC Link Configurations

- Unbalanced
  - —One primary and one or more secondary stations
  - —Supports full duplex and half duplex
- Balanced
  - —Two combined stations
  - —Supports full duplex and half duplex

HDLC Transfer Modes (1)

- Normal Response Mode (NRM)
  - —Unbalanced configuration
  - —Primary initiates transfer to secondary
  - —Secondary may only transmit data in response to command from primary
  - —Used on multi-drop lines
  - —Host computer as primary
  - —Terminals as secondary

HDLC Transfer Modes (2)

- Asynchronous Balanced Mode (ABM)
  - —Balanced configuration
  - —Either station may initiate transmission without receiving permission
  - —Most widely used
  - —No polling overhead

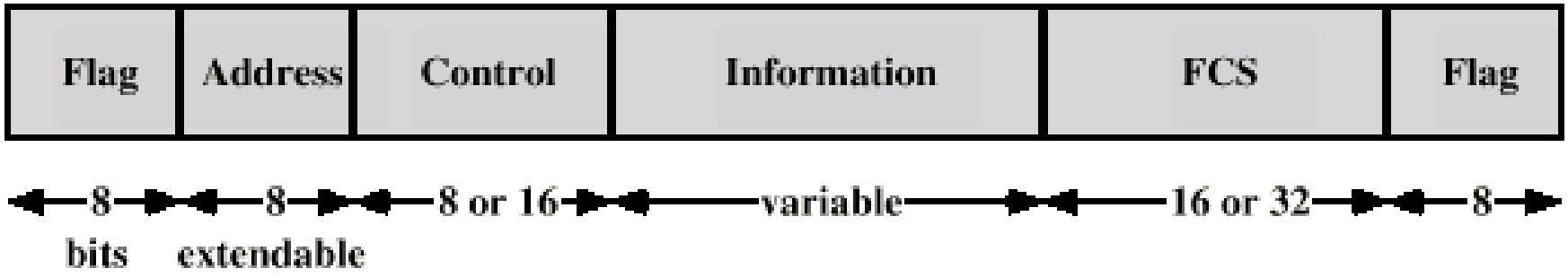
HDLC Transfer Modes (3)

- Asynchronous Response Mode (ARM)
  - —Unbalanced configuration
  - —Secondary may initiate transmission without permission form primary
  - —Primary responsible for line
  - —rarely used

Frame Structure

- Synchronous transmission
- All transmissions in frames
- Single frame format for all data and control exchanges

Frame Structure



(a) Frame format

Flag Fields

- Delimit frame at both ends
- 01111110
- May close one frame and open another
- Receiver hunts for flag sequence to synchronize
- Bit stuffing used to avoid confusion with data containing 01111110
  - 0 inserted after every sequence of five 1s
  - If receiver detects five 1s it checks next bit
  - If 0, it is deleted
  - If 1 and seventh bit is 0, accept as flag
  - If sixth and seventh bits 1, sender is indicating abort

Bit Stuffing

- Example with possible errors

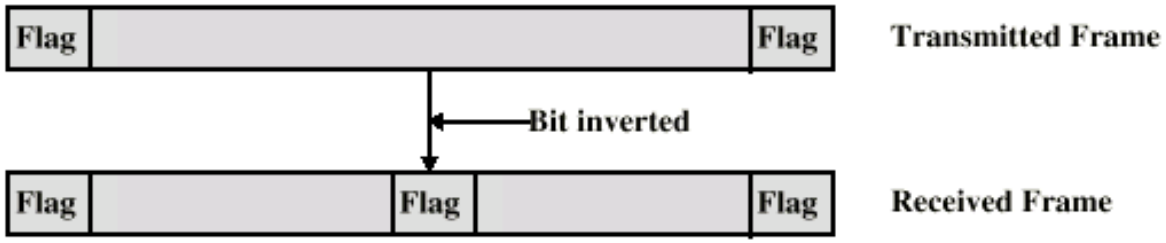
Original Pattern:

```
111111111111011111101111110
```

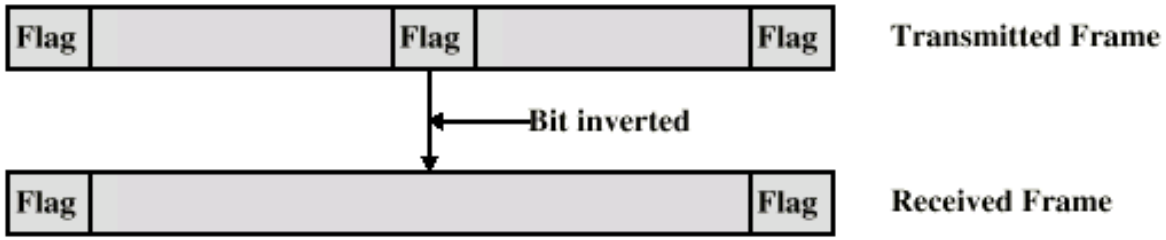
After bit-stuffing

```
111110111111011011111010111111010
```

(a) Example



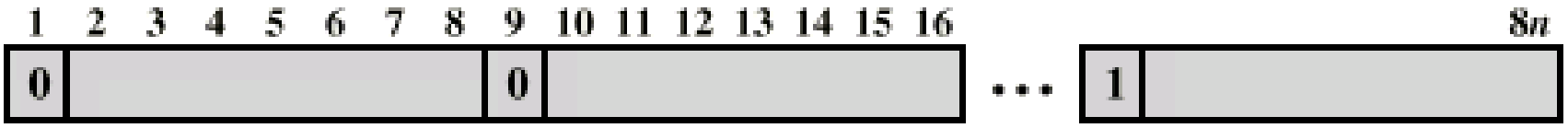
(b) An inverted bit splits a frame in two



(c) An inverted bit merges two frames

Address Field

- Identifies secondary station that sent or will receive frame
- Usually 8 bits long
- May be extended to multiples of 7 bits
  - LSB of each octet indicates that it is the last octet (1) or not (0)
- All ones (11111111) is broadcast

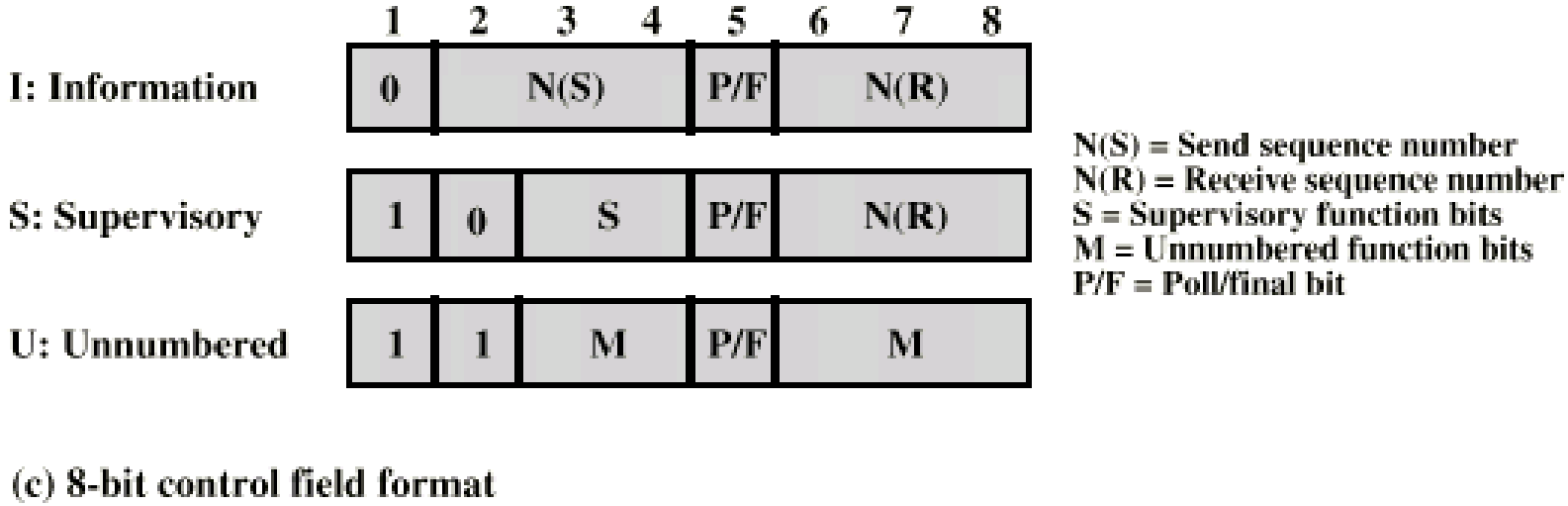


(b) Extended Address Field

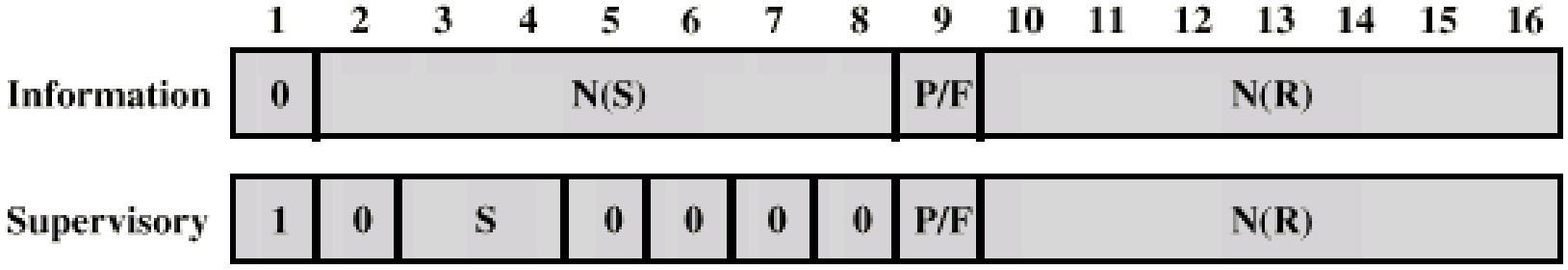
Control Field

- Different for different frame type
  - —Information - data to be transmitted to user (next layer up)
    - Flow and error control piggybacked on information frames
  - —Supervisory - ARQ when piggyback not used
  - —Unnumbered - supplementary link control
- First one or two bits of control filed identify frame type
- Remaining bits explained later

Control Field Diagram



(c) 8-bit control field format



(d) 16-bit control field format

Poll/Final Bit

- Use depends on context
- Command frame
  - —P bit
  - —1 to solicit (poll) response from peer
- Response frame
  - —F bit
  - —1 indicates response to soliciting command

Information Field

- Only in information and some unnumbered frames
- Must contain integral number of octets
- Variable length

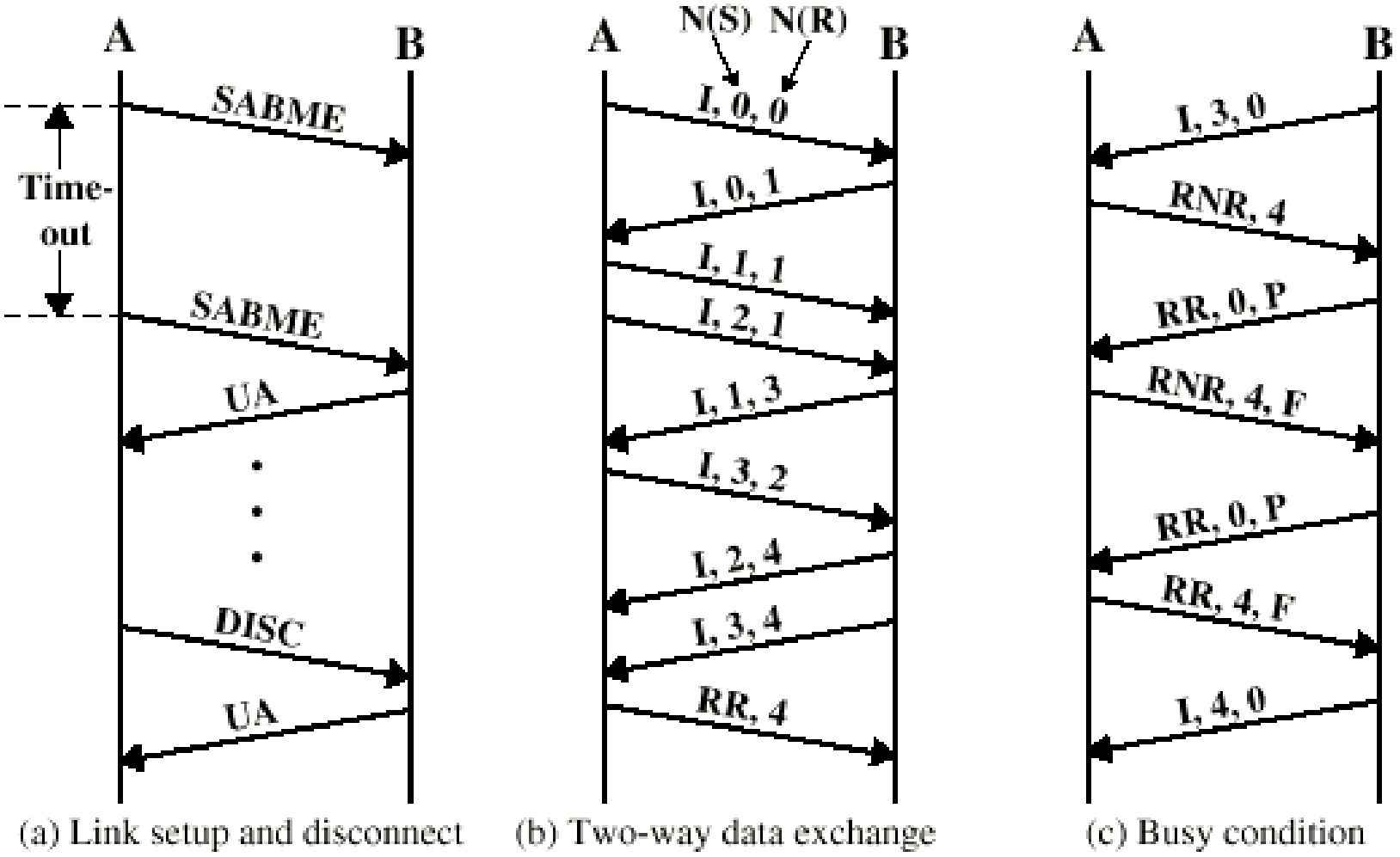
Frame Check Sequence Field

- FCS
- Error detection
- 16 bit CRC
- Optional 32 bit CRC

HDLC Operation

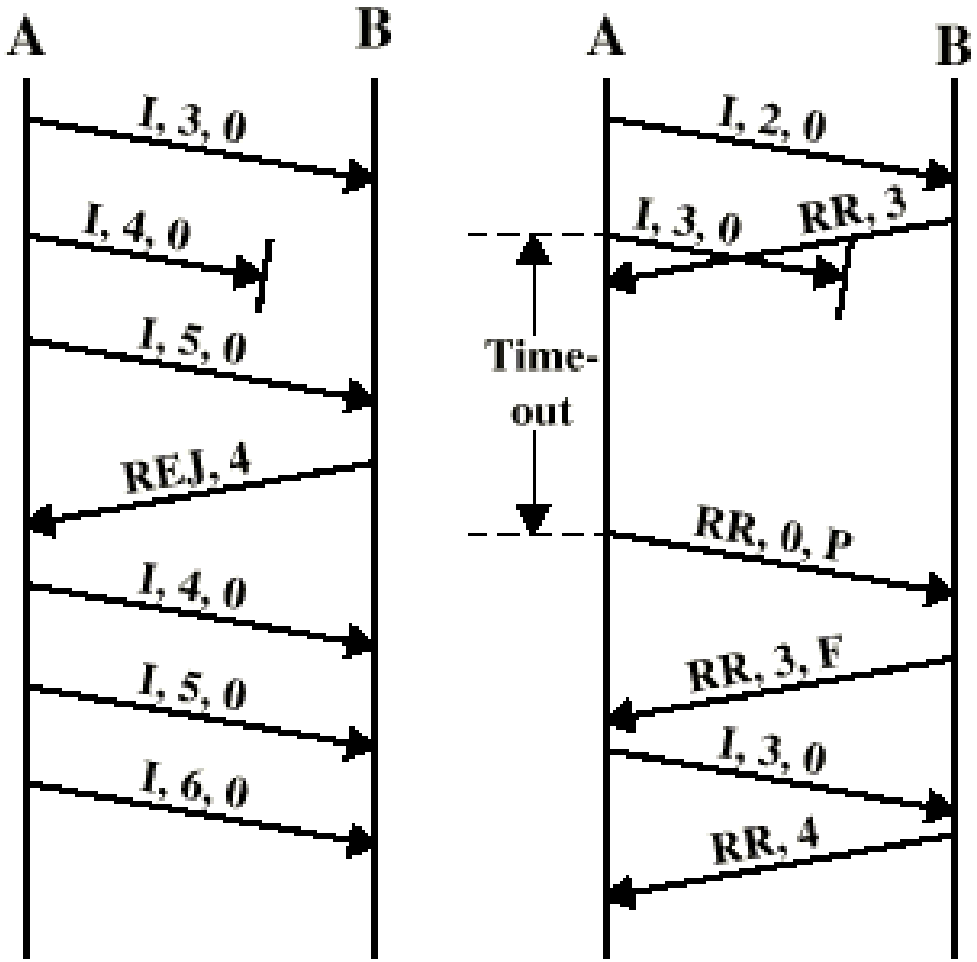
- Exchange of information, supervisory and unnumbered frames
- Three phases
  - —Initialization
  - —Data transfer
  - —Disconnect

Examples of Operation (1)



(a) Link setup and disconnect (b) Two-way data exchange (c) Busy condition

Examples of Operation (2)



(d) Reject recovery

(e) Timeout recovery

Required Reading

- Stallings chapter 7
- Web sites on HDLC